PEST RISK ANALYSIS FOR PEA CYST NEMATODE

PEST: Heterodera goettingiana

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COMMODITY: Peas

September 8, 1993

I. Introduction

This pest risk analysis is prepared by the Animal and Plant Health Inspection Service (APHIS) in response to the discovery of Pea cyst nematode, confirmed on pea plants taken from Skagit County, Washington the week of July 18, 1993. This is believed to be the first confirmed report of this nematode occuring in cultivated field conditions in the United States.

II. Summary of Life Cycle, Distribution, and Epidemiology

Heterodera goettingiana (Liebscher, 1892), whose common name is the Pea Cyst Nematode (PCN), is a plant parasitic nematode. These microscopic vermiform (worm-like) invertebrates are obligate parasites that feed on the roots of plants. PCN is in the group of nematodes called cyst nematodes.

Life Cycle: The developing nematode goes through its first stage of growth within the egg, leaving the cyst as a second stage juvenile (J2). After hatching, it migrates through the soil to the roots of plants. The J2's penetrate intracellularly into the root until they reach the stellar region where they establish a feeding site called a synchtia. At this point, the females become sedentary, and undergo three more molts (J3, J4, adult). As they continue to develop, they become swollen and the posterior portion of the body protrudes from the root.

The pea cyst nematode is bisexual; both males and females are present and mating is necessary to produce fertile eggs. However, the sex ratio can be affected by environmental conditions such as overcrowding and host changes (Di Vito and Greco, 1985). Under normal conditions, the males emerge from their last molt as free-living vermiforms and migrate to the females to mate. The female remains sedentary throughout her life cycle. A mated female produces about 100 eggs if the soil temperature and moisture levels are adequate. A soil temperature range of 10-15° C is necessary for egg development. The number of generations per year varies from one to three according to the host and environmental conditions (Di Vito, 1991).

Distribution: PCN has a wide distribution throughout the world, having been reported from Germany, The Netherlands, Belgium, Italy, the former USSR, Spain, Portugal, France, Great Britain, Israel, Algeria, Malta and Japan. It was reported from a greenhouse in Chicago, Illinois in 1940 and in a sample from Boise, Idaho in 1955 (Thorne, 1961) but it has not been reported in the U.S. since that time. In the early 1980's there was a tentative identification of PCN in Pennsylvania but enough material could not be collected to positively identify the nematode. The area was monitored for several years with negative results.

Symptoms: The symptoms of an infested field are similar to those caused by other plant parasitic nematode species. Infested plants tend to be stunted, with pale green leaves during the early stages of growth, becoming increasingly chlorotic. At the time of pod production, pod size and seed set may be reduced or seed may not be produced at all on heavily infested plants. Underground symptoms include poorly developed roots and a reduction in *Rhizobium* nodulations. Infested plants are also more susceptible to secondary infection by fungi and bacteria (Hagedorn, 1984).

III. Hosts

PCN generally infects leguminous plants (Fabaceae) but a few females can develop on the roots of *Asperula arvenisis* L., a weed not found in the U.S. (Di Vito and Greco, 1985). Other weeds common to European countries have also been listed a hosts.

Major hosts of economic importance include:

Broad Bean, *Vicia faba* L.
Field Pea, *Pisum sativum* L. var. arvense (L.) Poir.
Garden Pea, *Pisum sativum* L.
Gross pea, *Lathyrus cicera* L.
Lentils, *Lens culinaris* Medik.
Vetch, *Vicia* spp.

In addition to the above list of hosts, three other species of *Pisum*, 17 species of *Vicia*, and 9 species of *Lathyrus* have been recorded (Goodey, 1965; Di Vito, 1980). These are not listed because some of the species names are no longer valid.

There is some confusion in the literature concerning whether soybean *(Glycine max)* is a host for PCN. Franklin (1955) cites Liebscher's original paper as a source of *Soja hispida* = *Glycine hispida*. Christie (1959) lists *Glycine max* as a host but states that "some investigators regard the soybean as a questionable host." Di Vito and Greco (1985) and Di Vito (1980, 1991) list *Glycine hispida* as resistant to PCN but *Glycine max* as susceptible. However, *Glycine max* was not retested in the above studies but cited from Goodey, *et al.* (1965) who in turn cited Christie (1959). Further, Duke (1981) lists *Soja (Glycine) hispida* as a synonym for *Glycine max*. Therefore, it most likely that soybean is not a host of PCN.

Sweet pea, *Lathyrus odoratus* L. is listed as a host of PCN by Thorne (1961) and as the source of infection of the first finds of PCN in the United States. There is no information in the literature that Thorne actually conducted host tests for PCN using sweet pea. All other host tests indicate that sweet pea is resistant to PCN (Jones, 1950; Winslow, 1954; and Goodey *et al.*, 1965).

WORKSHEET FOR GENERIC PROCESS
(Place statement number under appropriate risk element)

IV. Rating Elements of the Generic Risk Model

A. PROBABILITY OF ESTABLISHMENT

- **The probability of the pest being on, with, or in commodities at the time of importation:** Rating = Uncertainty code =

- **The probability of the pest surviving in transit and successfully passing undetected at ports of entry:** Rating = Uncertainty code =

- **The probability of the pest successfully colonizing:** Rating = Uncertainty code =

- **The probability the pest is able to spread beyond the colonized area:** Rating = Uncertainty code =

B. CONSEQUENCES OF ESTABLISHMENT

- **The economic impact if established:** Rating = Uncertainty code =

- **The environmental impact if established:** Rating = Uncertainty code =

- **The impact from social and/or political influences:** Rating = Uncertainty code =

C: OVERALL PEST RISK POTENTIAL RATING = Uncertainty code =

V. Specific Questions:
Should APHIS be involved if PCN is found to be widespread?

VI. Recommendations:

STATEMENTS TO BE USED FOR THE WORKSHEET

1. It is estimated the PCN can survive in the absence of a host for as long as long as 5-10 years. Detection is difficult because the cysts are microscopic. However, PCN has been intercepted in seed lots and could easily be present in small bits of soil adhering to bulbs.

2. The literature indicates that there is a high probability PCN could be introduced with soil contaminated seed or plants. This pathway has a good chance of resulting in the establishment of the pest. The lack of importations from infested areas or strict seed certification and treatment programs could significantly reduce the probability of establishment. Unfavorable soil conditions or introduction outside of the nematode's specific temperature range or both are major factors which would reduce the possibility of establishment.

3. Approximately 17 states produce commercial quantities of edible beans and nine or more states produce green peas and lentils. It is estimated that the unchecked spread of PCN could have a $100 million impact on the economic host crops in the United States. The State of Washington alone produces approximately 32% of U.S. peas and lentils, valued at about $50 million per year. The potential loss of revenue for these agronomic crops is great without considering the possible effects on seed markets and other crops such as root crops and field grown ornamentals such as bulbs that might be affected by regulatory actions both within the U.S. and overseas. The use of vetch and related cover crops for forage in the Pacific Northwest is unknown but this is also likely to be impacted.

4. The strong economic impact of yield losses in affected states is likely to result in political concern and calls from the agriculture sector for regulatory or other action, particularly the pea industry. It is believed that the reduced availability of domestic peas as a result of PCN establishment could easily be offset by imports. Therefore, significant price increases would not be anticipated and little impact on the consumer sector is likely.

5. The dissemination of nematodes by irrigation water has been demonstrated conclusively in the Columbia basin of eastern Washington. From 25 to 200 nematodes per 3.8 liters of irrigation water were found, and 10% to 20% of these were plant parasitic nematodes. Aerial dissemination is also possible. *Globodera rostocheinsis*, the golden cyst nematode, can be blown by wind up to 285 m and still remain viable. About half of the genera of nematodes collected from dust traps or from the dirt of windblown soil in Texas were found to be plant parasitic nematodes.

6. Many cyst nematode species, including PCN, have been intercepted in seed lots contaminated with small amounts of soil and plant debris. Cyst nematodes are also easily moved with soil attached to equipment, conveyances, and footwear. Infested host plants, or plants in infested growing media, may also present a means of entry except that such importations are prohibited or would normally be subject to closer inspection unless moving from Canada.

7. Interceptions of plant parasitic nematodes have been made from soil on plants, farm machinery, soil on shoes, soil peds, and many other sources. In the eastern countries of England, PCN

incidence increased from nine infested fields to 47 infested fields from 1946 to 1956. In that area, there was at least one infested field in each county.

8. At present, there are no resistant cultivars available and no chemical control measures that are economically practical for use in the United States.

9. Under certain conditions, weeds could move into areas where a forage crop such as vetch was suppressed by PCN. Weed hosts in the U.S. are not known at this time. It is unlikely that nematicides would be authorized or practical, but environmental concerns would be raised if nematicdes were to be used.

10. PCN occurs in most pea growing areas of the world. The literature indicates that PCN can establish new populations at very low egg densities. For example, yield losses of 20% and 50% occurred at 3 and 8 eggs/g soil for pea, 5 and 15 eggs/g soil for broad bean, and 10 and 78 eggs/g soil for vetch. The number of eggs produced by PCN females in a field experiment were found to be independent of the initial population density or food source. Data indicate that under the same environmental conditions, reproduction of PCN on pea, broad bean, and vetch is similar.

11. The coevolution of cyst nematodes and their hosts has allowed both parasite and host to move together into new geographical areas and for the parasite to adapt quickly to new varieties of this host. PCN wide geographic range in Europe indicates that it is able to adapt to various soil types, climates, and a wide variety of leguminous hosts. Therefore, it is likely that PCN would adapt to a new habitat if certain environmental parameters were favorable.

12. The major nematode pest in agriculture throughout the world are generally those forms showing greatest development of the parasitic habit. Of these, the cyst nematodes and their relatives are the most highly adapted. The literature indicates that PCN is a limiting factor in the production of peas and related crops in areas of the world where it occurs. In some cases, total yield loss can occur from this pest. PCN is very damaging to pea and broad bean in southern Italy. The damage is much greater than reports of damage from England. The differences can probably be attributed to differences in cultivars and climate.

ANSWER SHEET FOR THE WORK EXERCISE OF THE GENERIC PROCESS

IV. Rating Elements of the Generic Risk Model

A. PROBABILITY OF ESTABLISHMENT

- **The probability of the pest being on, with, or in commodities at the time of importation:** ***High*** (uncertainty code = *MC*; see Appendix B for interpretation)

Many cyst nematode species, including PCN, have been intercepted in seed lots contaminated with small amounts of soil and plant debris (Epps, 1969; Mathur *et al.*, 1981). Cyst nematodes are also easily moved with soil attached to equipment, conveyances, and footwear. Infested host plants, or plants in infested growing media, may also present a means of entry except that such importations are prohibited or would normally be subject to closer inspection unless moving from Canada. There is currently no evidence to indicate that PCN occurs in Canada.

It is believed by the assessors that one very likely pathway for the introduction of PCN is with soil contaminated seed. Because of this, there is a high probability for introduction if commercial quantities of seed are imported from PCN infested areas. Soil contamination on admissible plant material such as bulbs could present another very good pathway.

- **The probability of the pest surviving in transit and successfully passing undetected at ports of entry:** ***High (MC)***

It is estimated the PCN can survive in the absence of a host for as long as 5-10 years (Di Vito and Greco, 1985). Detection is difficult because the cysts are microscopic. However, PCN has been intercepted in seed lots (Mathur *et al.*, 1981) and could easily be present in small bits of soil adhering to bulbs.

- **The probability of the pest successfully colonizing**: ***High (MC)***

PCN occurs in most pea growing areas of the world (Di Vito and Greco 1985). The literature indicates that PCN can establish new populations at very low egg densities. For example, yield losses of 20% and 50% occurred at 3 and 8 eggs/g soil for pea, 5 and 15 eggs/g soil for broad bean, and 10 and 78 eggs/g soil for vetch. (Greco *et al.*, 1991). The number of eggs produced by PCN females in a field experiment were found to be independent of the initial population density or food source (Jones and Perry 1978). Data indicate that under the same environmental conditions, reproduction of PCN on pea, broad bean, and vetch is similar (Greco *et al.*, 1991).

The coevolution of cyst nematodes and their hosts has allowed both parasite and host to move together into new geographical areas and for the parasite to adapt quickly to new varieties of its host. (Stone, 1979). PCN's wide geographic range in Europe indicates that it is able to adapt to various soil types, climates, and a wide variety of leguminous hosts. Therefore, it is likely that PCN would adapt to a new habitat if certain environmental parameters were favorable.

Based on the literature, it is believed by the assessors that the introduction of PCN with soil contaminated seed or plants would be very conducive to establishment provided the soil conditions and temperature range were suitable. A large portion of the U.S. where host plants are grown is probably suitable for the establishment of this pest.

- **The probability the pest is able to spread beyond the colonized area:** ***High (RC)***

The dissemination of nematodes by irrigation water has been demonstrated conclusively in the Columbia basin of eastern Washington. From 25 to 200 nematodes per 3.8 liters of irrigation water were found, and 10% to 20% of these were plant parasitic nematodes (Faulkner and Bolander, 1966). Aerial dissemination is also possible. *Globodera rostocheinsis*, the golden cyst nematode, can be blown by wind up to 285 m and still remain viable (Chitwood, 1951). About half of the genera of nematodes collected from dust traps or from the dirt of windblown soil in Texas were found to be plant parasitic nematodes (Orr and Newton, 1971).

Interceptions of plant parasitic nematodes have been made from soil on plants, farm machinery, soil on shoes, soil peds, and many other sources (Hagge, 1969; Epps, 1969; Girard, 1969). In the eastern counties of England, PCN incidence increased from nine infested fields to 47 infested fields from 1946 to 1956. In that area, there was at least one infested field in each county (Brown, 1958).

- **Discussion of the Overall Probability of Establishment:**

The literature indicates that there is a high probability PCN could be introduced with soil contaminated seed or plants. This pathway has a good chance of resulting in the establishment of the pest. The lack of importations from infested areas or strict seed certification and treatment programs could significantly reduce the probability of establishment. Unfavorable soil conditions or introduction outside of the nematode's specific temperature range or both are major factors which would reduce the possibility of establishment.

B. CONSEQUENCES OF ESTABLISHMENT

- **The economic impact if established:** *High (MC)*

"The major nematode pests in agriculture throughout the world are generally those forms showing greatest development of the parasitic habit. Of these, the cyst nematodes and their relatives are the most highly adapted". (Stone, 1985). The literature indicates that PCN is a limiting factor in the production of peas and related crops in areas of the world where it occurs. In some cases, total yield loss can occur from this pest. PCN is very damaging to pea and broad bean in southern Italy. The damage is much greater than reports of damage from England. The differences can probably be attributed to differences in cultivars and climate (Greco, *et al.*, 1991).

The pea cyst nematode can persist in the soil for several years in the absence of host plants, and damage to pea crops has occurred after an interval of 10 to 12 years (Brown, 1958). Total loss of yield can occur as nematode populations increase in number under continuous cropping to peas or other susceptible crops. (Hagedorn, 1984). Cropping sequences have been shown to have no effect on the rate of decline of either eggs or cysts of PCN. Three years after rotation with a non-host, the egg population of PCN was still 48% of its original number. It has been suggested that a minimum five year rotation is necessary to realize a useful reduction in the population (Moriaty, 1963).

The crop and the initial nematode population levels dictate crop rotation and nematicide strategies. A host crop can generally be grown one year in three with low initial population densities; two crops in three years if both rotation and nematicides are utilized. (Ferris and Greco, 1992). Few if any nematicides are available for the control of PCN and those available are not economically feasible to apply in commercial cultivated conditions. (Hagedorn, 1984). At present, there are no resistant cultivars available and no chemical control measures that are economically practical for use in the United States. Rotation with non-hosts is not likely to be practical in most situations because PCN populations in the soil decrease very slowly.

Approximately 17 states produce commercial quantities of edible beans and nine or more states produce green peas and lentils. It is estimated that the unchecked spread of PCN could have a $100 million impact on the economic host crops in the United States (PAD, 1993). The State of Washington alone produces approximately 32% of U.S. peas and lentils, valued at about $50 million per year (USDA Agricultural Statistics, 1992). The potential loss of revenue for these agronomic crops is great without considering the possible effects on seed markets and other crops such as root crops and field grown ornamentals such as bulbs that might be affected by regulatory actions both within the U.S. and overseas. The use of vetch and related cover crops for forage in the Pacific Northwest is unknown but this is also likely to be impacted.

- **The environmental impact if established:** *Low (MC)*

Under certain conditions, noxious weeds could move into areas where a forage crop such as vetch was suppressed by PCN. Weeds hosts in the U.S. are not known at this time. It is unlikely that nematicides would be authorized or practical, but environmental concerns would be raised if nematicides were to be used.

- **The impact from social and/or political influences:** *Medium (RC)*

The strong economic impact of yield losses in affected states is likely to result in political concern and calls from the agriculture sector for regulatory or other action, particularly the pea industry. It is believed that the reduced availability of domestic peas as a result of PCN establishment could easily be offset by imports. Therefore, significant price increases would not be anticipated and little impact on the consumer sector is likely.

C. Overall Pest Risk Potential Rating: *High (RC)*

The method of estimation is described in The Generic Pest Risk Assessment Process (Orr and Cohen, 1991). Uncertainty codes are described in Appendix B.

V. Specific Questions:

Should APHIS be involved if PCN is found to be widespread?
Probably not. There are no economically or environmentally acceptable control measures to eradicate a population of cyst nematodes. However, certain regulatory measures can slow man-assisted spread. The implementation of such measures could be effective in preventing spread from the Pacific Northwest to Midwestern and Eastern pea growing areas, enhancing the effect of natural geographic barriers. Certification programs for seed and ornamentals falls within the purview of the states.

Is there any way to control the spread except through regulatory action?
No. Cyst nematodes are easily transported by many means, including farm machinery. A strict quarantine could address proper decontamination of such of equipment or prevent it from moving into uninfested areas. Only very strict regulations have controlled the spread of the golden cyst nematode on potato in New York state. However, the quarantine on soybean cyst nematode was not effective, probably because infested soybeans are grown in the major flyways for migratory waterfowl that tend to feed on stubble in these fields during migration. Soil peds have also been shown to be a source of infestation of cyst nematodes.

How important is natural spread?
Since PCN is closely associated with agronomic crops, it would probably not spread naturally unless the fields were subject to flooding or if fields were left fallow in areas prone to strong winds that could blow the infested soil. Weed hosts in the USA are not known at this time, nor is the potential for movement with migratory birds.

What is the actual extent of the current infestation?
The presence of PCN has been confirmed in two counties in Washington state. Survey information currently available for Washington, surrounding states, and British Columbia, indicate that the pest does not occur in other areas.

Are there treatment options available to minimize the effects on host crops?
Most nematicides are limited in their use due to ground water contamination and other problems. The nematicides labeled for legumes that could be used in Washington state are unknown at this time. Emergency use labels might be considered to minimize the damage caused by PCN in localized areas. However, nematicides are not effective for eradication because they do not kill every nematode in an infested area. Some tolerance to PCN has been reported for some pea varieties but whether the varieties are suitable for the infested area is unknown.

VI. Summary and recommendations:

Pea cyst nematode has been demonstrated to be a limiting factor for pea production in areas of the world where it occurs. Under some conditions, up to 75% crop loss has been reported. Total loss of the crop can occur in extreme conditions.

Cyst nematodes are easily moved from one location to another by many means and the movement of cysts with infected crop seed or plants is very likely. Once established, control is difficult and eradication is unlikely.

The following is recommended:

- Conduct delimiting survey or evaluate recent survey information or both to determine the extent of infestation and possibly identify pathways.
- Weigh the costs/benefits of regulating the movement of root crops, host seed, ornamentals and equipment from infested areas; consider developing certification programs.
- Disinfest equipment moving from infested areas.
- Continue to evaluate costs and benefits as information and actions develop.

PEST RISK ANALYSIS FOR PEA CYST NEMATODE

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I. Introduction

This pest risk analysis is prepared by the Animal and Plant Health Inspection Service (APHIS) in response to the discovery of Pea cyst nematode, confirmed on pea plants taken from Skagit County, Washington the week of July 18, 1993. This is believed to be the first confirmed report of this nematode occuring in cultivated field conditions in the United States.

II. Summary of Life Cycle, Distribution, and Epidemiology

Heterodera goettingiana (Liebscher, 1892), whose common name is the Pea Cyst Nematode (PCN), is a plant parasitic nematode. These microscopic vermiform (worm-like) invertebrates are obligate parasites that feed on the roots of plants. PCN is in the group of nematodes called cyst nematodes.

Life Cycle: The developing nematode goes through its first stage of growth within the egg, leaving the cyst as a second stage juvenile (J2). After hatching, it migrates through the soil to the roots of plants. The J2's penetrate intracellularly into the root until they reach the stellar region where they establish a feeding site called a synchtia. At this point, the females become sedentary, and undergo three more molts (J3, J4, adult). As they continue to develop, they become swollen and the posterior portion of the body protrudes from the root.

The pea cyst nematode is bisexual; both males and females are present and mating is necessary to produce fertile eggs. However, the sex ratio can be affected by environmental conditions such as overcrowding and host changes (Di Vito and Greco, 1985). Under normal conditions, the males emerge from their last molt as free-living vermiforms and migrate to the females to mate. The female remains sedentary throughout her life cycle. A mated female produces about 100 eggs if the soil temperature and moisture levels are adequate. A soil temperature range of 10-15° C is necessary for egg development. The number of generations per year varies from one to three according to the host and environmental conditions (Di Vito, 1991).

Therefore, it most likely that soybean is not a host of PCN.

Sweet pea, *Lathyrus odoratus* L. is listed as a host of PCN by Thorne (1961) and as the source of infection of the first finds of PCN in the United States. There is no information in the literature that Thorne actually conducted host tests for PCN using sweet pea. All other host tests indicate that sweet pea is resistant to PCN (Jones, 1950; Winslow, 1954; and Goodey *et al.*, 1965).

IV. Rating Elements of the Generic Risk Model

A. PROBABILITY OF ESTABLISHMENT

- **The probability of the pest being on, with, or in commodities at the time of importation:** ***High*** (uncertainty code = *MC*; see Appendix B for interpretation)

Many cyst nematode species, including PCN, have been intercepted in seed lots contaminated with small amounts of soil and plant debris (Epps, 1969; Mathur *et al.*, 1981). Cyst nematodes are also easily moved with soil attached to equipment, conveyances, and footwear. Infested host plants, or plants in infested growing media, may also present a means of entry except that such importations are prohibited or would normally be subject to closer inspection unless moving from Canada. There is currently no evidence to indicate that PCN occurs in Canada.

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- **The probability of the pest surviving in transit and successfully passing undetected at ports of entry:** ***High*** *(MC)*

It is estimated the PCN can survive in the absence of a host for as long as 5-10 years (Di Vito and Greco, 1985). Detection is difficult because the cysts are microscopic. However, PCN has been intercepted in seed lots (Mathur *et al.*, 1981) and could easily be present in small bits of soil adhering to bulbs.

- **The probability of the pest successfully colonizing**: ***High*** *(MC)*

PCN occurs in most pea growing areas of the world (Di Vito and Greco 1985). The literature indicates that PCN can establish new populations at very low egg densities. For example, yield losses of 20% and 50% occurred at 3 and 8 eggs/g soil for pea, 5 and 15 eggs/g soil for broad

B. CONSEQUENCES OF ESTABLISHMENT

- **The economic impact if established:** ***High*** *(MC)*

"The major nematode pests in agriculture throughout the world are generally those forms showing greatest development of the parasitic habit. Of these, the cyst nematodes and their relatives are the most highly adapted". (Stone, 1985). The literature indicates that PCN is a limiting factor in the production of peas and related crops in areas of the world where it occurs. In some cases, total yield loss can occur from this pest. PCN is very damaging to pea and broad bean in southern Italy. The damage is much greater than reports of damage from England. The differences can probably be attributed to differences in cultivars and climate (Greco, *et al.*, 1991).

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The crop and the initial nematode population levels dictate crop rotation and nematicide strategies. A host crop can generally be grown one year in three with low initial population densities; two crops in three years if both rotation and nematicides are utilized. (Ferris and Greco, 1992). Few if any nematicides are available for the control of PCN and those available are not economically feasible to apply in commercial cultivated conditions. (Hagedorn, 1984). At present, there are no resistant cultivars available and no chemical control measures that are economically practical for use in the United States. Rotation with non-hosts is not likely to be practical in most situations because PCN populations in the soil decrease very slowly.

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How important is natural spread?
Since PCN is closely associated with agronomic crops, it would probably not spread naturally unless the fields were subject to flooding or if fields were left fallow in areas prone to strong winds that could blow the infested soil. Weed hosts in the USA are not known at this time, nor is the potential for movement with migratory birds.

What is the actual extent of the current infestation?
The presence of PCN has been confirmed in two counties in Washington state. Survey information currently available for Washington, surrounding states, and British Columbia, indicate that the pest does not occur in other areas.

Are there treatment options available to minimize the effects on host crops?
Most nematicides are limited in their use due to ground water contamination and other problems. The nematicides labeled for legumes that could be used in Washington state are unknown at this time. Emergency use labels might be considered to minimize the damage caused by PCN in localized areas. However, nematicides are not effective for eradication because they do not kill every nematode in an infested area. Some tolerance to PCN has been reported for some pea varieties but whether the varieties are suitable for the infested area is unknown.

VI. Summary and recommendations:

Pea cyst nematode has been demonstrated to be a limiting factor for pea production in areas of the world where it occurs. Under some conditions, up to 75% crop loss has been reported. Total loss of the crop can occur in extreme conditions.

Cyst nematodes are easily moved from one location to another by many means and the movement of cysts with infected crop seed or plants is very likely. Once established, control is difficult and eradication is unlikely.

The following is recommended:

- Conduct delimiting survey or evaluate recent survey information or both to determine the extent of infestation and possibly identify pathways.

- Weigh the costs/benefits of regulating the movement of root crops, host seed, ornamentals and equipment from infested areas; consider developing certification programs.

- Disinfest equipment moving from infested areas.

- Continue to evaluate costs and benefits as information and actions develop.

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Appendix B: Key to Uncertainty Codes

Uncertainty codes are a subjective expression of the degree of certainty associated with ratings provided by the assessor(s). The codes are found in parenthesis following the estimation for each element. Abbreviations used in this document are as follows:

VC	Very Certain	As certain as possible
RC	Reasonably Certain	A high degree of certainty
MC	Moderately Certain	More certain than not
RU	Reasonably Uncertain	A high degree of uncertainty
VU	Very Uncertain	A guess